HEALTH RISKS AMONG SUBMARINE PERSONNEL IN THE U.S. NAVY, 1974-1979

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SUMMARY

Problem

U.S. Navy submarine duty exposes personnel to a unique environment that could have adverse health effects. Submarine environmental health effects need to be evaluated to ensure future successful submarine missions.

Objectives

The objective of this study was to determine health risks associated with submarine duty in the U.S. Navy by comparing hospitalization rates of submariners with surface ship personnel on illnesses hypothesized to be related to submarine duty.

Approach

The Service History file maintained by the Naval Health Research Center in San Diego was searched for all personnel during 1974-1979 who had served aboard nuclear- and diesel- powered submarines (n=68,475). A random sample of enlisted personnel who had served aboard surface ships of similar crew size as submarines was selected as a control group (n=77,541). Age-adjusted hospital admission rates for 16 major diagnostic categories and submarine associated specific diagnoses were calculated and compared for submarine and surface ship personnel. Relative risks were calculated and 95 percent confidence intervals were computed to determine significant differences in hospitalization rates.

Results

The overall hospitalization rate for submariners was statistically significantly lower than the overall hospitalization rate for surface ship personnel (RR=.74, $p < .05$). Submarine personnel did not have statistically significantly higher hospitalization rates for any diagnostic category including illnesses hypothesized to be related to submarine duty. The relative risk of hospital admissions was greater for submarine personnel for other diseases of the kidney and ureter and for myocardial infarction; however, the differences were not statistically significant.

Conclusions

Submarine duty does not appear to adversely affect the health of U.S. Naval personnel. Results show that submariners have a lower total hospitalization rate than personnel of surface ships with a similar crew size. Submarine personnel had lower hospitalization rates for nearly all

diagnostic categories and for those diagnoses hypothesized to be associated with the submarine environment. Several factors may account for these results including stringent screening of submariners, higher levels of education among submariners, difficulty of evacuation from a submarine, and the healthy-worker effect.

Recommendations

Future research should consider the long-term health effects of submarine duty. An assessment of the contribution of screening to the decrease in hospitalization rates observed in this study could be done. Hospitalization rates for personnel screened and accepted for submarine service, but who never served aboard a submarine, could be determined. A comparison of this group with submariners may help to separate the contribution of screening in decreasing risk of hospitalization.

Health Risks Among Submarine Personnel in the U.S. Navy, 1974-1979

U.S. Navy personnel who serve aboard submarines are exposed to extreme environmental challenges. At any given time, several thousand American submariners are sealed in tiny living spaces, exposed to manufactured air and artificial light, and submerged to great depths for an excess of 60 days. During this time, their job is to operate an extremely complicated and potentially dangerous machine. Their confinement in this small, artificial ecologic unit provides an opportunity to observe clinical illness under unique conditions.

Until 1968, the submarine atmosphere chronically exposed personnel to CO_2 levels in the range of .79 to 1.2 percent (Gortner, Messier, Heyder, and Schaefer, 1971; Hughes, 1969; Peck, 1971; Gude and Schaefer, 1969; Piebenga and Shiller, 1968; Weybrew, Bryan, and Noddin, 1978). High CO_2 levels in the submarine atmosphere were suspected of contributing to dental calculus (Piebenga and Shiller, 1968), and elevated CO_2 levels have been demonstrated to cause changes in calcium metabolism and to cause kidney calcification (Schaefer, Pasquale, Messier, and Niemoeller, 1979; Messier, Hayder, Braithwaite, McCluggage, Peck, and Schaefer, 1979; Tansey, Wilson and Schaefer, 1979) and respiratory disease (Gude and Schaefer, 1969; Sphar and Evans, 1976) in human and animal studies. Comparison with surface ship personnel revealed a higher incidence of ureteral calculi in submarine personnel (Tansey et al., 1979). After 1968, improvements in the CO_2 scrubbers resulted in a decrease in the average ambient CO_2 level to .5 percent and an abrupt decline in respiratory disease as well as a decrease in the number of cases of ureteral calculi (Tansey et al., 1979).

Another important aspect of the submarine environment is the prolonged isolation. This imposed isolation can involve 60 to 90 days of submerged cruising, and researchers have found several problems may arise such as fatigue, muscular tension, low motivation, disruption of circadian cycles, and minor emotional disturbances (Mills, 1966; Schaefer, Clegg, Carey, Dougherty, Weybrew, 1967; Serxner, 1968). Similar symptoms have been observed in other extreme, isolated environments such as Antarctic research stations during the austral winter (Gunderson, 1963, 1973; Palmai, 1963) and undervater research labs (Radloff and Helmreich, 1968).

The submarine environment's effect on cardiovascular health has been considered in a number of studies. Submariners are treated to large quantities of what is reputed to be the best food in the Navy (Bennett and Bondi, 1981; Shivertaker, 1974). Several studies have addressed the related topics of physical activity limitations and weight gain during a submarine cruise (Bennett and Bondi, 1981; Vickers, Conway, Hodgdon, and Duett, 1982; Bondi, 1983; Beare et al., 1981). Findings showed that, as a direct result of limited exercise space, the physical activity level is low; however, weight gain by the crew was minimal and did not present a problem. Shivertaker (1974) found that personnel engaged in duty at sea in submarines had higher cholesterol levels than personnel who were qualified for submarine duty but who had not made a cruise. Possible causes suggested were emotional stress, high cholesterol diet, and lack of physical activity. However, subsequent research on cardiovascular risk (Tansey et al., 1979; Tappan, Mooney, Jacey, Heyder, 1979; Tappan and Weybrew, 1982) found such rates to be very low. Nevertheless, there was a significant relation of cardiovascular risk to length of submarine duty.

Other submarine environment-related problems include a lack of appropriate environmental cues being implicated in circadian cycle disintegration and a decrement in sleep quality (Schaefer and Clegg, 1966; Schaefer, Kerr. Buss, and Haus, 1979; Beare, Bondi, Biersner. and Naitoh, 1981). Isolation in a constant and closed environment was related to mental disorders (Tansey, Wilson, and Schaefer, 1979; Weybrew and Noddin, 1979a, 1979b) and the spread of infectious mononucleosis (Storrie, Sphar, Sawyer, and Evans, 1976). Also, the confining nature of the submarine, with its constant requirement for optical accommodation and convergence was related to visual deterioration (Schwartz and Sandberg, 1954; Luria, Newmark, Beatty, 1970; Kinney, Luria, McKay, and Ryan, 1979).

Tansey and his colleagues (1979) compared the health of submariners with surface fleet personnel between 1963 and 1973. They reported that surface fleet personnel were at higher risk than submariners for respiratory, traumatic, gastrointestinal, skin, infections, and miscellaneous illness. Submariners, on the other hand, had higher illness rates in genitourinary, systemic, cranial, and neuropsychiatric illness categories. Illness data

were obtained from the medical sections and from medical patrol reports for the submarines, and only those illnesses occurring at sea that resulted in at least one sick day lost from duty were included. An important difference between the Tansey study and this study is that the illness data are hospitalizations rather than shipboard sick call reports. Illness rates based on hospitalizations provide a more stringent and less variable measure for comparison of morbidity differences between submarine and surface ship personnel.

The present study compares the health of submariners with surface fleet personnel during the 1974 to 1979 period. The objective of this study was to determine if there are any health risks associated with submarine duty in the U.S. Navy. An attempt was made to determine whether submariners are at risk for several illnesses that were hypothesized, based on previous studies, to be associated with the submarine environment (e.g., cardiovascular disease, calculus of kidney and ureter, genitourinary disease, and respiratory disease). It was hypothesized that the submariners would have higher hospitalization rates for the submarine associated illnesses and for total hospitalization rate and that these higher rates were due to aspects of the submarine environment.

METHOD

The Naval Health Research Center in San Diego, California, maintains computerized Service History and Medical Inpatient files for active duty Naval enlisted personnel. The Service History file was searched for all personnel who had served aboard nuclear- and diesel-powered submarines during the period 1974-1979. A control group, consisting of a random sample (approximately 50%) of enlisted personnel who had served aboard surface ships of approximately the same crew size as submarines during the same period, also was identified from the Service History file. Ship types represented in the control group included Destroyer, Guided Missile Destroyer, Frigate, and Guided Missile Frigate.

In order to control for the potential confounding influence of sex and race on hospital admission rates and because of the small number of personnel represented in other groups (e.g., female, black, hispanic), only white males were selected for examination in this study.

Diagnoses were in accordance with the International Classification of Disease Adapted for Use in the United States, Eighth Revision. Sixteen of

eighteen major diagnostic categories were included in the study. Complications of pregnancy, childbirth and the puerperium, and certain causes of perinatal morbidity and mortality were eliminated because they were not relevant to the study. Hospitalization rates were expressed as the number of hospital admissions per 100,000 person-years.

Age-adjusted hospital admission rates were calculated using the direct method of adjustment (Lilienfeld, 1980). The standard population was the sum of the two groups. Age-adjusted rates for submariners and surface ship personnel were compared using relative risks. Ninety-five percent confidence intervals were used to assess statistical significance of observed differences in hospitalization rates (Lilienfeld, 1980). T-tests were used to assess statistical significance of the descriptive variables (McNemar, 1969).

RESULTS

The search of the Service History file identified 68,475 submarine personnel and 77,541 surface ship controls. The number of enlisted white males in the submarine group during this period averaged 43,541 per year and the number of enlisted white males in the control group averaged 45,151 per year. The submarine group and surface ship controls were further compared on several descriptive variables in Table 1. This table shows that personnel in the submarine group were older and had a higher education level and paygrade than the surface ship control group.

Table 1. Comparison of Submarine Personnel and Surface Ship Personnel by Age, Education, and Paygrade.

	Submarine			Surface Ship		
Characteristic	N	Mean	Standard Deviation	N	Mean	Standard Deviation
Age	68,448	28.0*	6.45	77,519	26.7	6.84
Education	68,475	12.1*	.94	77,522	11.7	1.05
Paygrade	68,450	5.5*	1.48	77,526	4.7	1.65

* Significantly higher at the $p < .001$

During the study period, enlisted white males serving aboard submarines had 16,092 hospital admissions in Navy medical facilities, surface ship controls accounted for 23,156 hospital admissions. Table 2 provides a distribution of hospital admissions by diagnostic category with submarine associated diagnoses under the appropriate diagnostic category. Table 2 also contains the age-adjusted hospitalization rates for submarine and surface ship personnel and estimates of relative risk for submarine personnel.

Table 2. Total Age-Adjusted Hospitalization Rates per 100,000 Person-Years and Relative Risks Among Submarine Personnel and a Comparison Sample of Surface Ship Personnel, White Male Enlisted Personnel, 1974-1979.

Diagnostic Category and selected diagnoses	Submarine Personnel (261,248 Person-years)				Surface Ship Personnel (270,906 Person-years)				
			95% Confidence Limits				95% Confidence Limits		Relative
	N	Rate	Lower	Upper	N	Rate	Lower	Upper	Risk
INFECTIVE AND PARASITIC DISEASES	1253	505.2	443.8	566.5	1724	614.9	557.3	672.4	0.82
Tuberculosis	18	6.8	0	17.0	29	10 7	0.2	21.2	0.63
Viral Hepatitis	125	47.9	33.3	62.5	222	81.6	63.8	99.5	0.59*
Mononucleosis	128	50.7	33.2	68.2	203	73.2	55.2	91.2	0.69
Venereal Diseases	52	19.8	8.2	31.4	119	44.0	30.4	57.7	0.45
NEOPLASMS	316	120.4	73.3	167.5	367	135.6	106.2	165.0	0.89
ENDOCRINE, NUTRITIONAL AND METABOLIC DISEASES	117	44.3	26.0	62.7	128	47.7	26.5	68.8	0.93
Diabetes Mellitus	47	17.6	3.7	31.6	55	20.4	5.7	35.2	0.86
DISEASES OF BLOOD AND BLOOD-FORMING TISSUE	40	15.5	5.2	25.8	73	26.5	13.9	39.1	0.58
MENTAL DISORDERS	1888	724.6	650.1	799.0	3409	1252.2	1161.1	1343.2	0.58*
Alcohol Abuse	630	242.1	199.6	284.6	1645	607.3	540.6	674.0	0.40*
Drug Abuse	103	40.0	25.2	54.8	215	76.8	56.6	96.9	0.52*
Psychophysiological Disorders	26	9.9	3.5	16.3	45	16.3	7.5	25.0	0.61
Schizophrenias	95	36.0	24.6	47.3	152	56.1	40.4	71.7	0.64
Affective Disorders	23	8.8	0.5	17.1	28	10.3	1.6	19.0	0.85
Neuroses	215	82.4	59.3	105.4	226	83.4	51.3	115.5	0.99
Personality Disorders	354	136.6	111.1	162.0	547	198.9	167.8	230.0	0.69*
DISEASES OF THE NERVOUS SYSTEM AND SENSE ORGANS	430	164.5	119.5	209.6	724	267.1	208.9	325.2	0.62

Table 2. (continued)

Diagnostic Category and selected diagnoses			95% Confidence Limits				95% Confidence Limits		Relative Risk
	N	Rate	Lower	Upper	N	Rate	Lower	Upper	
DISEASES OF THE CIRCULATORY SYSTEM	541	205.4	141.8	269.0	639	236.3	171.8	300.8	0.87
Essential Benign Hypertension	51	19.4	5.4	33.3	57	21.2	3.5	38.9	0.91
Myocardial Infarct	28	10.7	0	25.7	25	9.3	0	24.7	1.16
Chronic Ischemic Heart Disease	48	18.3	0	40.0	49	18.1	0	37.7	1.01
Angina Pectoris	11	4.2	0	14.4	12	4.4	0	10.0	0.96
DISEASES OF THE RESPIRATORY SYSTEM	1935	771.7	690.7	852.8	2471	886.4	812.2	960.6	0.87
Acute Upper Respiratory Infection	303	126.3	93.4	159.1	366	126.2	98.1	154.2	1.00
Influenza	19	7.6	0.7	14.4	39	14.0	5.6	22.3	0.54
Pneumonia	424	176.4	137.1	215.8	607	212.2	175.7	248.7	0.83
Asthma	29	11.1	3.8	18.4	51	18.6	7.6	29.5	0.60
DISEASES OF THE DIGESTIVE SYSTEM	1770	683.6	587.6	779.5	2260	830.4	748.5	912.2	0.82
Dental Diseases	196	76.0	54.6	97.3	261	95.8	74.1	117.6	0.79
DISEASES OF THE GENITO-URINARY SYSTEM	595	226.5	171.7	281.3	929	342.0	300.2	383.8	0.66*
Calculus of Kidney and Ureter	126	47.6	19.1	76.1	125	46.2	30.1	62.3	1.03
Other Diseases of Kidney and Ureter	22	8.3	0.9	15.6	17	6.3	0	13.9	1.31
DISEASES OF THE SKIN AND SUBCUTANEOUS TISSUE	989	391.2	340.4	442.1	1552	561.7	508.4	615.1	0.70*
DISEASES OF THE MUSCULO-SKELETAL SYSTEM	1587	602.2	534.3	670.1	2071	765.6	690.5	840.8	0.79*
CONGENITAL ANOMALIES	172	67.5	46.0	88.9	270	97.7	75.4	120.1	0.69
SYMPTOMS AND UNSPECIFIED CONDITIONS	678	261.3	207.3	315.3	892	324.8	264.6	385.0	0.80
ACCIDENTS, POISONINGS AND VIOLENCE	3125	1201.6	1114.6	1288.6	4944	1808.7	1710.9	1906.6	0.66*
Fractures	1070	410.5	363.6	457.4	1567	575.5	523.0	628.0	0.71*
Concussion	202	79.0	58.1	99.9	447	162.8	135.8	189.7	0.48*
Strains and Sprains	414	158.3	131.2	185.5	614	225.2	184.2	266.1	0.70
Contusions	129	50.0	33.2	66.8	310	113.2	91.2	135.1	0.44*

Table 2. (continued)

Diagnostic Category and selected diagnoses	N	Rate	95% Confidence Limits Lower	Upper	N	Rate	95% Confidence Limits Lower	Upper	Relative Risk
Open Wounds	207	79.6	58.3	100.9	447	162.7	135.3	190.1	0.49*
Burns	70	27.1	10.8	43.4	138	50.1	20.3	80.0	0.54
SUPPLEMENTARY EXAMS	652	261.7	216.2	307.3	702	250.9	211.6	290.1	1.04
TOTAL HOSPITAL ADMISSIONS	16092	6248.8	6019.0	6478.6	23156	8448.7	8217.0	8680.5	0.74*

* $p < .05$

Submariners did not have statistically significantly higher hospitalization rates for any diagnostic category nor for any of the hypothesized submarine associated illnesses. Overall the hospitalization rate for submariners (6,248.8 per 100,000 person-years) is significantly less than the rate of total hospitalizations for surface ship personnel (8,448.7 per 100,000 person years). Submarine personnel had significantly fewer hospital admissions for accidents, poisonings and violence, mental disorders, diseases of the genitourinary system, diseases of the skin and subcutaneous tissue, and diseases of the musculoskeletal system.

The highest rates of hospital admissions in both groups were for accidents, poisonings and violence; submarine personnel, however, exhibited significantly fewer hospital admissions for this diagnostic category than the surface ship controls. Hospitalization rates for fractures, concussions, contusions, and open wounds were significantly lower, approximately one-half as high among submariners as among surface ship personnel.

The submarine personnel also appeared to be at significantly reduced risk for mental disorders. While this reduced risk was evident in all of the individual diagnoses examined, statistical significance was obtained only for the diagnoses of alcohol abuse, drug abuse, and personality disorders. Again, the hospitalization rates for submariners were approximately one-half those of the surface ship controls. Finally, submarine personnel also displayed significantly lower hospitalization rates for viral hepatitis (RR=.59).

The relative risk of hospital admissions with respect to a few selected diagnoses were greater among the submarine personnel. Most notable was the

relative risk for other diseases of the kidney and ureter (RR=1.31), and myocardial infarction (RR=1.16). As mentioned, in no instance did any of the excess risks in the submarine group achieve statistical significance.

DISCUSSION

Submarine personnel were found to have lower hospitalization rates for nearly all diagnostic categories and individual diagnoses examined. Thus, the prolonged isolation associated with submarine duty does not appear to adversely affect the health of personnel. Similar results were found in a related study in which Naval personnel who experienced prolonged isolation associated with winter-over duty in the Antarctic had a significantly lower rate of first hospitalizations than a control group of personnel who were screened and accepted for such duty but who were assigned elsewhere (Palinkas, 1986).

The results of this study are in agreement with previous research which concluded that submariners are a relatively healthy group (Herman, 1982; Tappan, Jacey, Heyder and Harvey, 1979; Tansey et al., 1979). Most of the individuals in the submarine group have served on nuclear-powered submarines during their Naval careers. These individuals must undergo stringent psychological and medical screening prior to assignment aboard a nuclear submarine because of the relatively long periods of isolation during deployment. It appears that this screening eliminates many individuals at high risk for illness. Another factor that may contribute to lower hospitalization rates is that submarine personnel also tend to be better educated in order to qualify for many of the rates on board nuclear submarines (Weybrew and Noddin, 1979). In this study, the submarine personnel had a mean of 12.1 years of education, while the control group had a mean of 11.7 years of education. Among Naval personnel, there is a negative linear relationship between education and the incidence of disease and illness (Gunderson, Rahe and Arthur, 1970; Rahe, Gunderson and Arthur, 1970; Rahe, Gunderson, Pugh, Rubin and Arthur, 1972). Because hospital admission rates among Naval personnel are known to be affected by occupation (Gunderson and Colcord, 1982), occupational differences in the submariner and control groups may also account for the observed differences in hospitalization rates. Finally, long periods of deployment may also preclude submarine personnel on active duty from being admitted to hospital facilities on an inpatient basis for relatively minor conditions. Rather, these individuals may receive treatment from medical personnel aboard ship. A study by Nice (1984) found that the rates of medical

evacuations from submarines are among the lowest of all Naval ships, suggesting both that serious medical events rarely occur aboard submarines during deployment and that minor medical events are treated by available medical personnel.

In contrast to the Tansey study which found higher rates of illness for submariners in genitourinary and neuropsychiatric categories, the present study did not support these results; submarine personnel had significantly lower illness rates for diseases of the genitourinary system and for mental disorders. A possible explanation for this discrepancy is that the illness data for the surface ships used in the Tansey study was provided from a study conducted at the Naval Health Research Center in which ship corpsmen filled out a sick call card for each sick call visit during a 7-8 month deployment. As mentioned, Tansey's submarine illness data was obtained from medical patrol reports, and only those illnesses that resulted in one sick day lost from duty were counted. The fact that Tansey's results were based on the comparison of data from two separately conducted studies, collected under different conditions and with different instructions given to the participating corpsmen, may render such illness rate comparisons ineffectual. Further support for this conclusion is provided by other data from a study by Gunderson (1976) which showed that the rate of inpatient neuropsychiatric admissions for submariners was less than one-half of the rate for surface ship personnel.

Another problem in the Tansey study is that of disparate crew sizes of the vessels being compared. The submarines had a smaller crew (n=140) and, therefore, it could be assumed that the sick submariner would, in many cases, be returned to work after being medically attended because of a shortage of personnel. These cases would not be counted in the illness rates because they did not miss a day of work. Conversely, the surface ship crew (n=300) with more personnel available. may have been more readily given a day off for illness.

There are a number of limitations of the present study. Outpatient data were not available. Hospital admissions among submariners may not completely reflect their health status. Evacuations from submarines are discouraged for two reasons: first, the logistical difficulty, and, second, reluctance to disclose position when on a mission.

Another potential confounding factor that may affect the hospitalization rates among submariners is the healthy-worker effect (Kelsey, Thompson and Evans, 1986). Naval personnel are required to maintain an acceptable level of physical fitness and mental well-being in order to remain submariners. Personnel who become ill are likely to be transferred from submarine duty and assigned elsewhere.

In summary, the rate of total hospitalizations among submarine personnel is 74 percent of the rate of total hospitalizations among surface ship personnel. This reduced risk was observed in all but 1 of 16 diagnostic categories and most individual diagnoses examined. Only rarely did hospitalization rates among submarine personnel exceed rates among the surface ship personnel and in no instances did excesses reach statistical significance. Psychological and medical screening procedures, higher levels of education among submarine personnel, and medical practices associated with long periods of isolation during deployment, difficulty of evacuation from a submarine, and the healthy-worker effect may account for these differences.

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This study evaluated health risks associated with U.S. Navy submarine duty by comparing hospitalization rates of submariners with surface ship personnel. The groups were compared on age-adjusted hospitalization rates for 16 major diagnostic categories and several specific diagnoses postulated to be submarine associated. Submarine personnel did not have significantly higher hospitalization rates for any diagnostic categories nor for any of the submarine associated illnesses. Submariner relative risk of hospital admissions was greater for a few selected diagnoses but statistical significance was not attained. The health status of U.S. Navy personnel does not appear to be adversely affected by submarine duty. Submarine personnel had lower hospitalization rates for nearly all of the diagnostic categories examined. Reasons for these lower rates may be stringent screening of submariners, higher levels of education among submariners, difficulty of evacuation from a submarine, and the healthy worker effect.

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